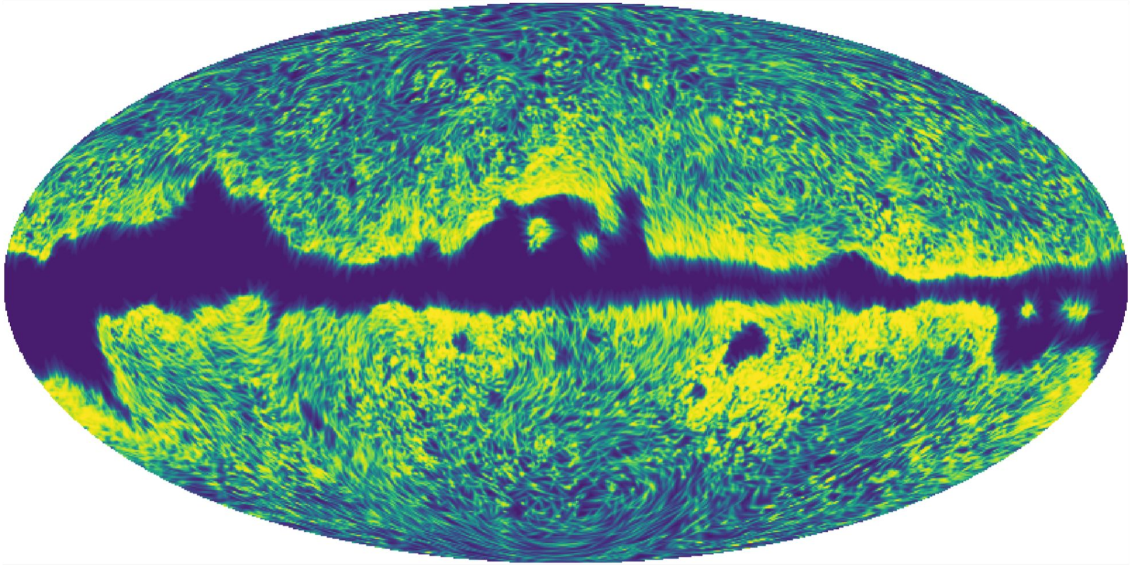
A new 3D model of Galactic microwave foreground dust emission based on filaments



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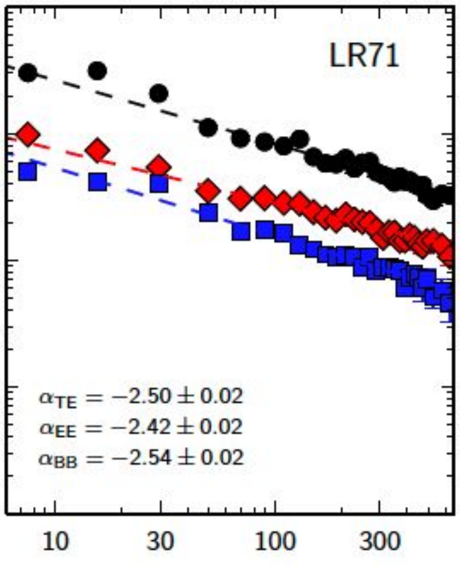
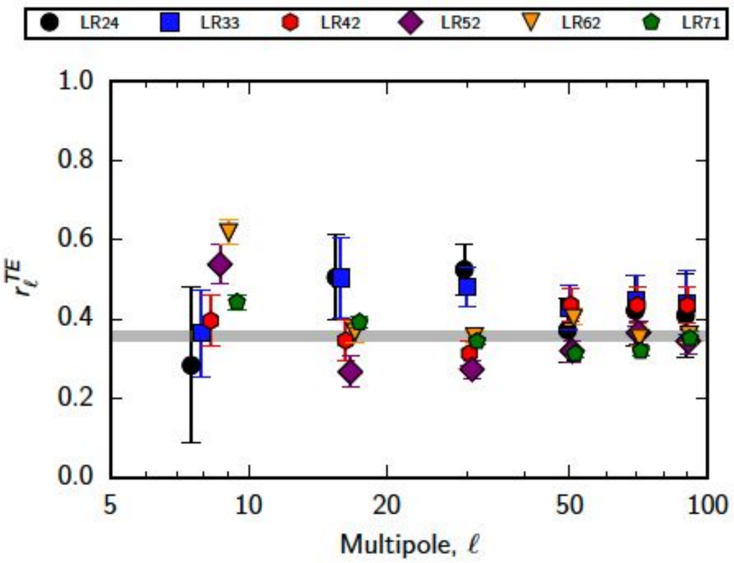
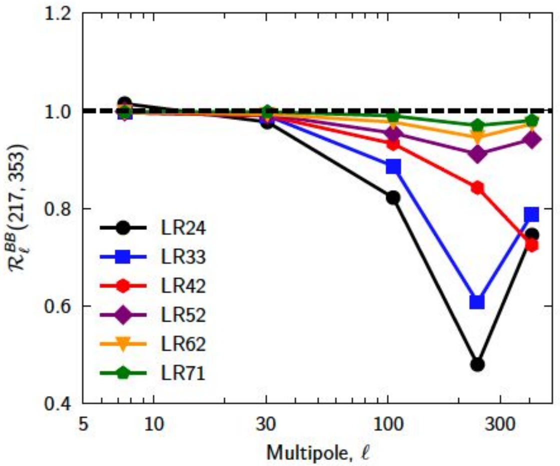
Planck 2018 results for 353GHz dust:

- Spectra consistent with power-law, that have similar but not exactly the same slope
- BB power about half of EE power
- TE correlation rTE = TE/sqrt(TT*EE) ~ 0.35
- TE/EE power ~ 2.7
- non-zero TB, EB consistent with zero
- Frequency decorrelation between 217 and 353 GHz ~ 0.989 +- 0.005





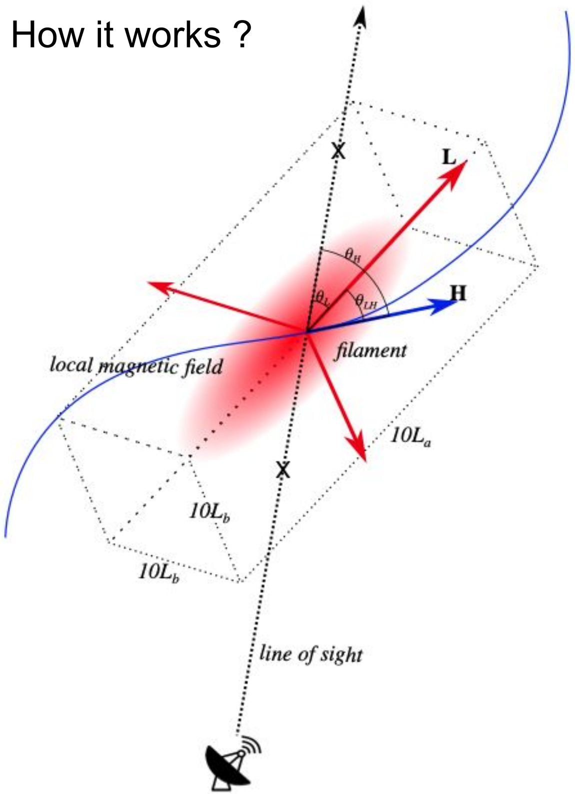


Planck 2018 results XI 1801.04945

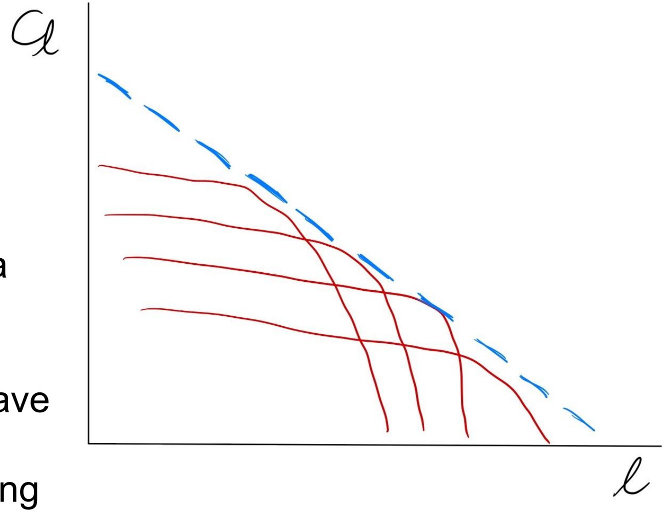
Filamentary structure can reproduce these features

Huffenberger et al. 2020 (Arxiv:1906.10052)

How it works ?

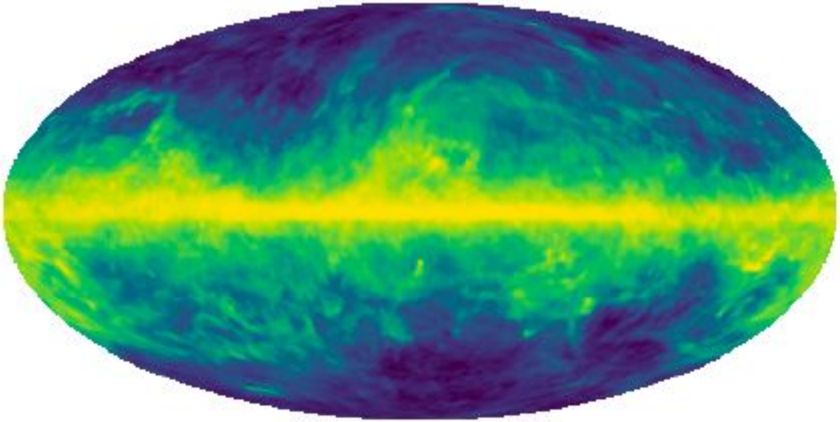


Filaments are placed at random (but following a weighted template map), then rotated by θ_{LH} from a Gaussian with zero mean and std=RMS(θ_{LH})=10 degrees. The filaments have 1 long semi-axis L_a and 2 short semi-axes L_b, defining an axis ratio $\varepsilon = L_b/L_a$. The sizes are drawn from a Pareto distribution $p(L_a) \sim L_a^{-2.445}$

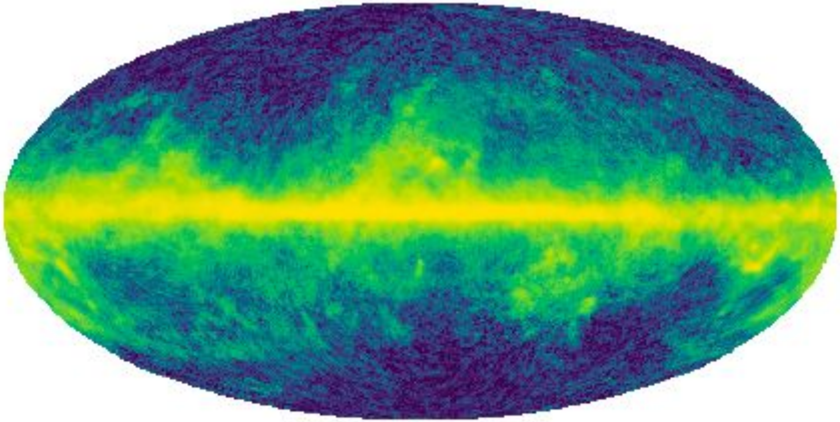


Results: Full sky T map

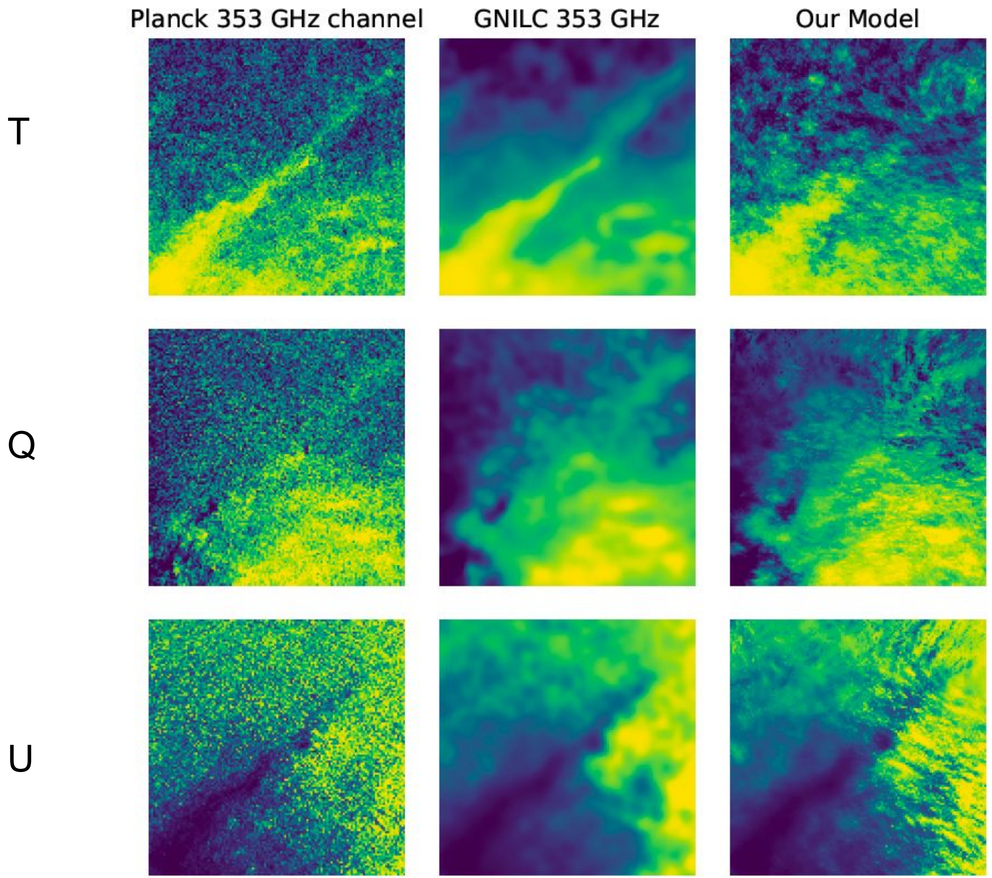
GNILC 353 GHz



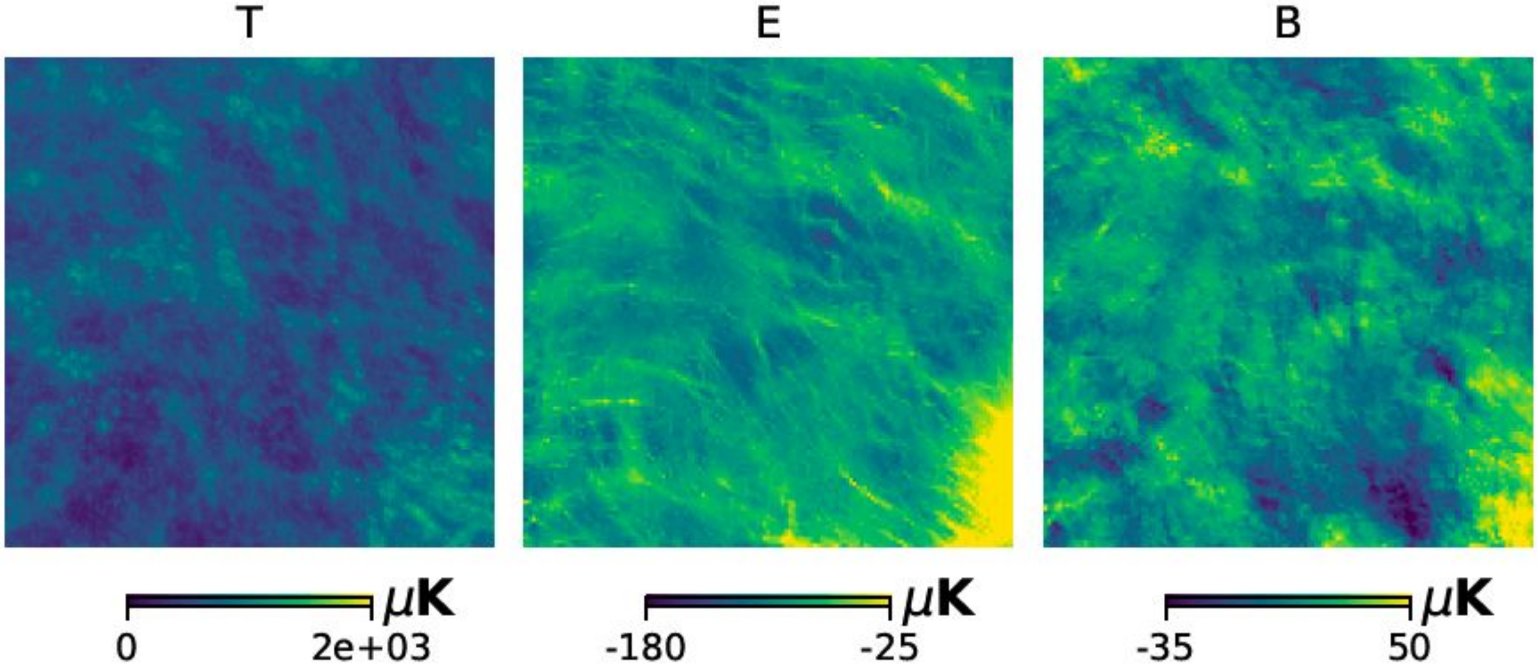
our Model



Results: 30x30 degrees close up

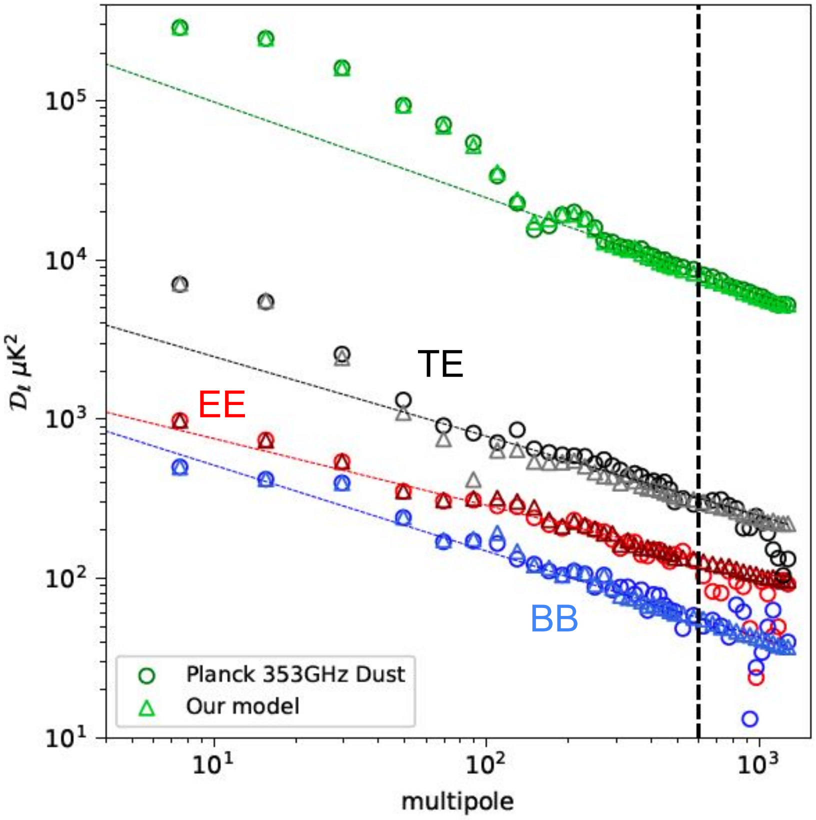


Results: 10x10 degrees centered at Gal. North Pole



Mean E and B of the patch are subtracted

Our model can match the Planck 353 GHz dust spectra



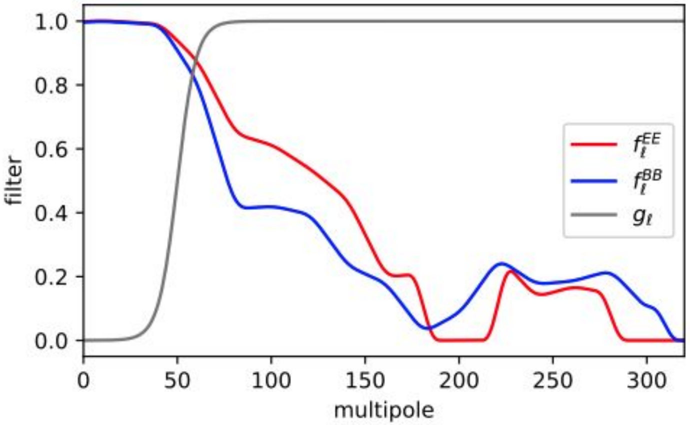
Using the same binning scheme and LR71 mask from Planck 2018 XI. We also extend to ell=1300

Filling of large scales for Polarization

Our model cannot reproduce the large scale QU because of the lack of an accurate model of the entire Galactic magnetic field

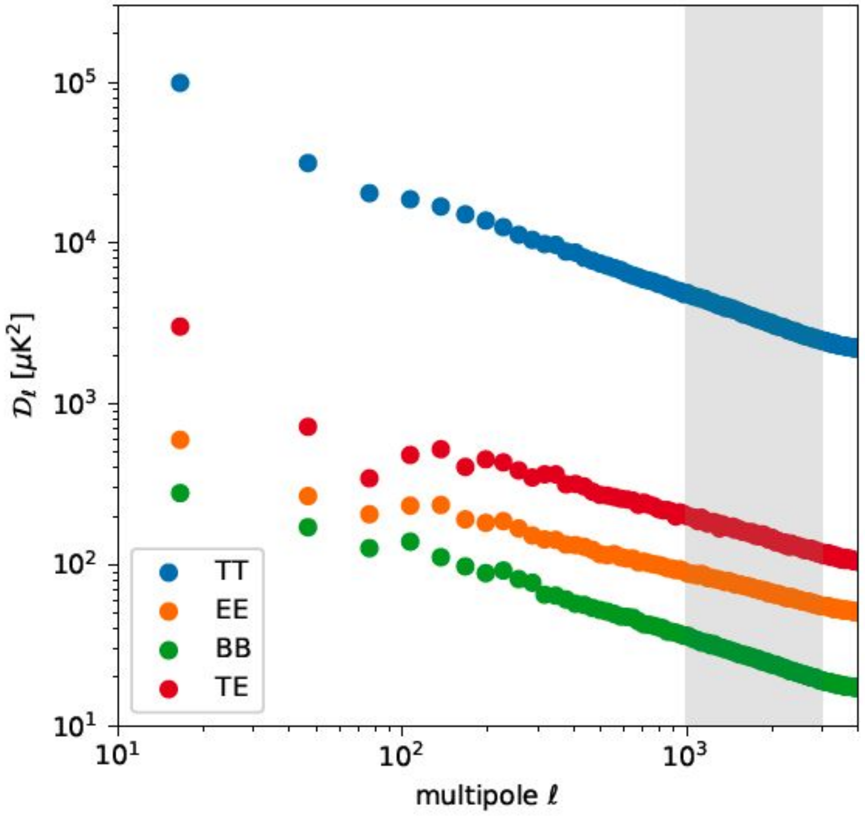
We suppress the large scale from our model (ell < 100) and fill in (ell < 300) with the Planck 353 GHz map, using an ad-hoc filter such that

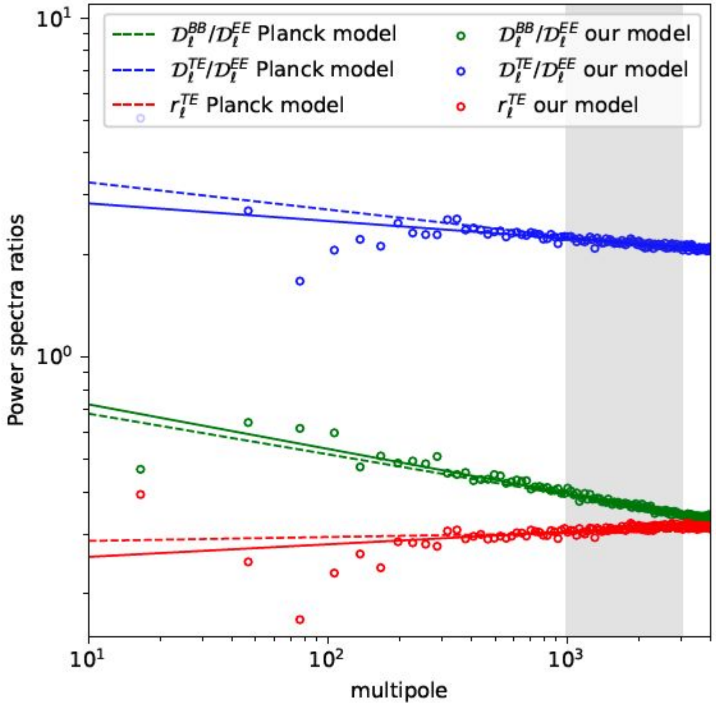
$$\mathcal{D}_\ell^{XX,\mathrm{target}} = (f_\ell^{XX})^2 \mathcal{D}_\ell^{XX,\mathrm{template}} + g_\ell^2 \mathcal{D}_\ell^{XX,\mathrm{filaments}}$$



EE and BB ad-hoc filter, smoothed by a Hamming window to avoid sharp edges (ringing)

Results: Power spectra and ratios at very small scales





Using Galactic mask with fsky=0.7 from Planck DR2

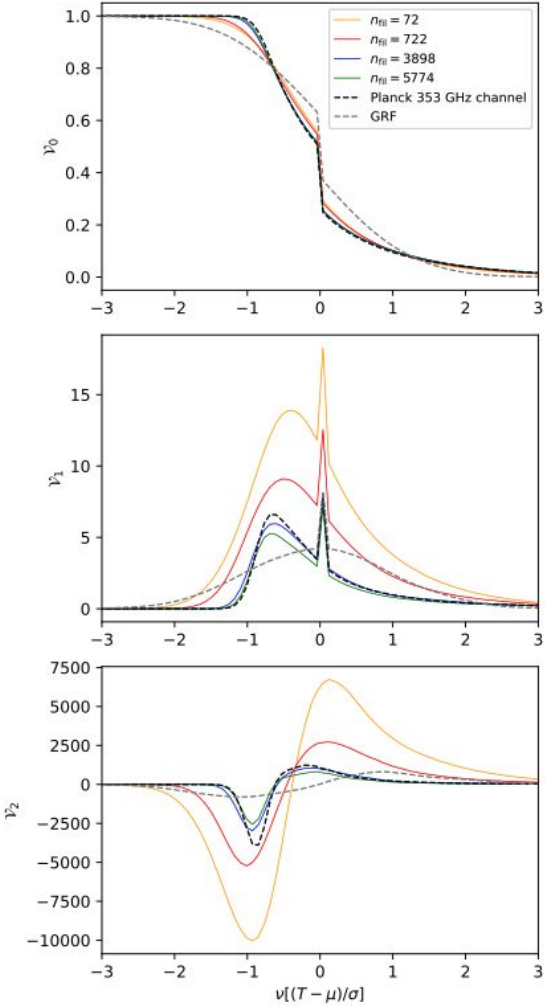
Density of filaments and non-Gaussianity

By changing the total number of filaments, we change the density of filaments per solid angle.

This lets us fix a best fit density that matches the TT spectrum from Planck

n_{fil} = 3898 filaments deg^{-2} [I_{353} / MJysr^{-1}]

We measure the Minkowski functionals (on the curved sky) of the T map in the LR71 mask, compared to Planck 353 GHz channel (with the same noise and beam).

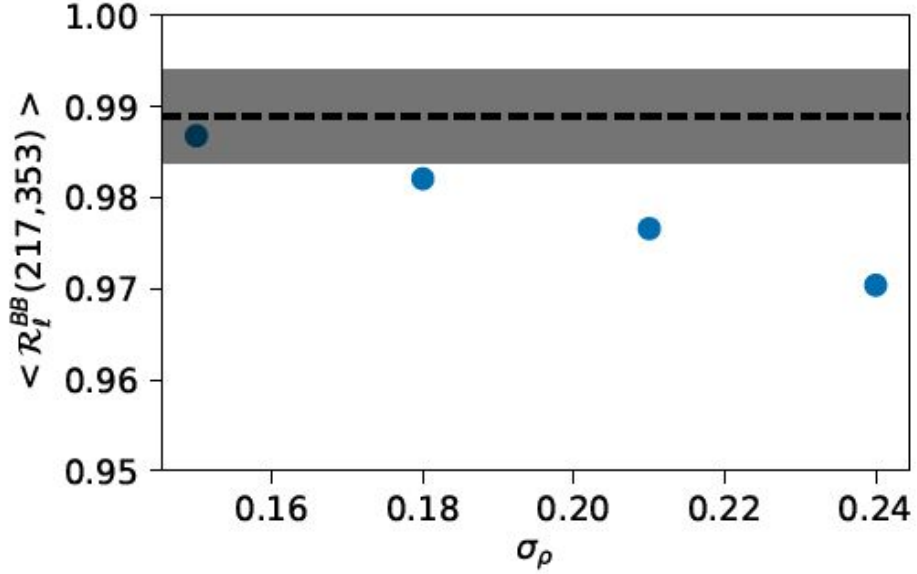


Frequency decorrelation

The BB decorrelation ratio $R^{BB}(217,353)$ = BB(217x353)/sqrt(BB(217x217)*BB(353x353)) is nearly constant in our filament model ell > 300. We put the variability of a MBB in the β_{dust} index.

$$\beta_{\rm dust} = \log\left[\alpha(1+\rho)\frac{e^{217{\rm GHz}h/kT_{\rm dust}}-1}{e^{353{\rm GHz}h/kT_{\rm dust}}-1}\right] / \log(217/353) - 3$$

Pelgrims et al. 2021 finds that σ_ρ=0.15 works well in LOS in the Galactic Poles. We can fine-tune the decorr. by changing σ_ρ



Mean small-scale decorr. ratio from our model. The line is the measurement by Planck 2018 XI in mask LR71 and 50<ell<150.

Discussion

- DustFilaments model (**Hervías-Caimapo & Huffenberger 2021, Arxiv:2107.08317**)

- Observations:
    - Higher resolution (than Planck) would improve the constraints of the model (CCAT-prime, SO and CMB-S4 280 GHz channel), especially small scale

- Filaments seem like a good alternative, but we cannot match the exact small scale non-Gaussianity
    - What is the profile of a filament?
    - Is all dust inside the filaments or is there a significant fraction outside of them?
    - If I observe dust near Galactic poles at very high resolution, will I see filaments? Will it look like the Galactic plane emission ?

- Realism from 3D Galactic structure/ISM studies:
    - 3D dust density from extinction surveys.
    - Galactic magnetic field, we use Jansson & Farrar 2012 model, but more realism is necessary e.g. something that includes features .

- Unified model: Synchrotron and AME ?